

Chapter 28 Transformer

Does voltage level changing

→ on ϕ or ϕ lines?

primary
secondary
↓

↳ Distribution stations → we need step-up transformer

↳ In our house → step down

11kV → 400 Volt

out of generator when step-up in houses

* DC transformer

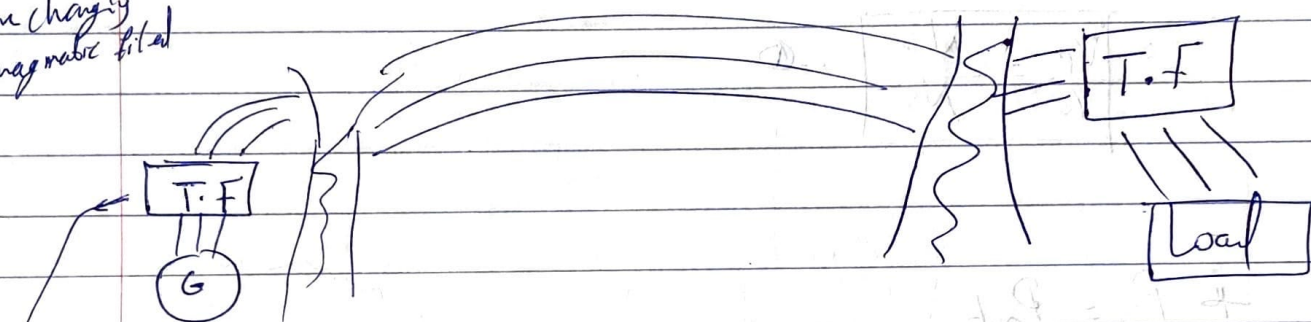
→ ϕ or ϕ lines

التيار الكهربائي في الكابلات

we're using

AC to have time changing magnetic field

* High efficiency of transferring in long distances



$$P = I^2 R \rightarrow I \text{ is non-linear}$$

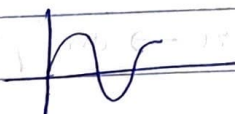
losses depends on I , ϕ or ϕ lines

step up transformer ϕ or ϕ lines

* Time change flux, & a closed loop → EMF is induced

$$e_{ind} = \frac{d\phi}{dt}$$

changing of polarity



$$e_{indp} = e_{inds}$$

Φ is fixed from the source & it is the same delving to secondary but I can change the # of turns

$$* e_{indp} = N_p \frac{d\Phi_p}{dt} \rightarrow \text{Faraday's}$$

$$e_{inds} = N_s \frac{d\Phi_s}{dt}$$

$$\% \quad V_p = N_p \frac{d\Phi}{dt}$$

$$V_s = N_s \frac{d\Phi}{dt}$$

$$\Rightarrow \boxed{\frac{V_p}{V_s} = \frac{N_p}{N_s}} \quad \dots \textcircled{1}$$

$$* P_{in} = P_{out}$$

$$I_p V_p = I_s V_s$$

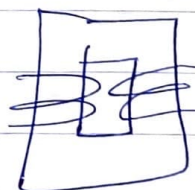
$$\boxed{\frac{I_p}{I_s} = \frac{V_s}{V_p} = \frac{N_s}{N_p}} \quad \dots \textcircled{2}$$

* If $N_2 > N_1 \Rightarrow$ step up

* 3 phase transformer $\Rightarrow$ 3 of single phase Transformer in each primary & secondary



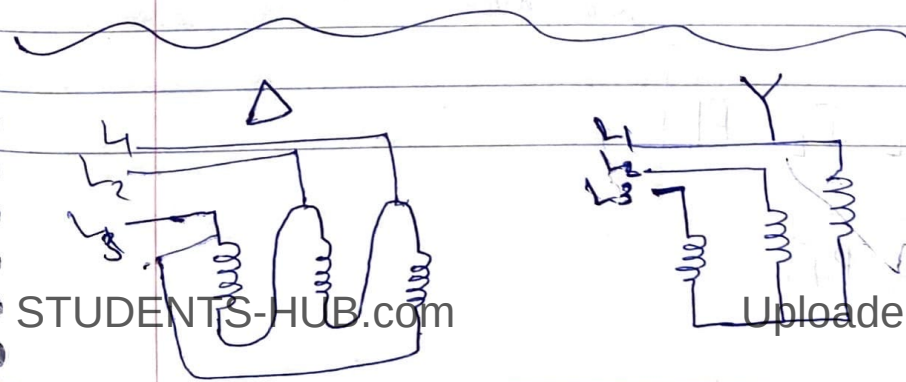
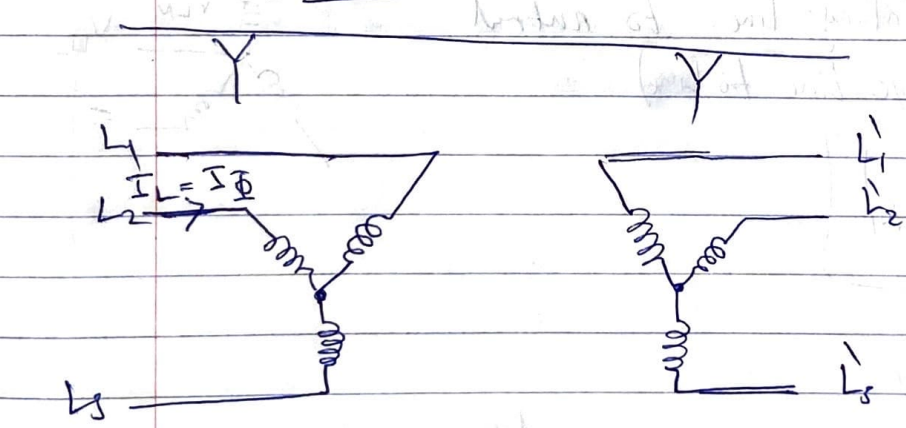
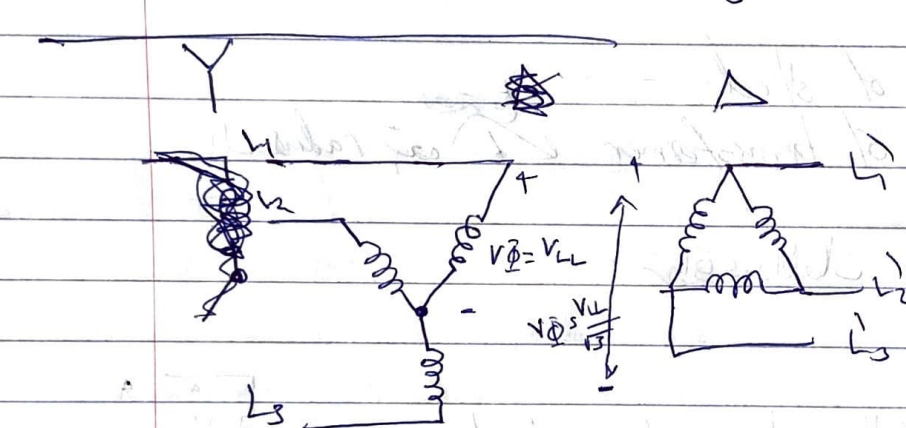
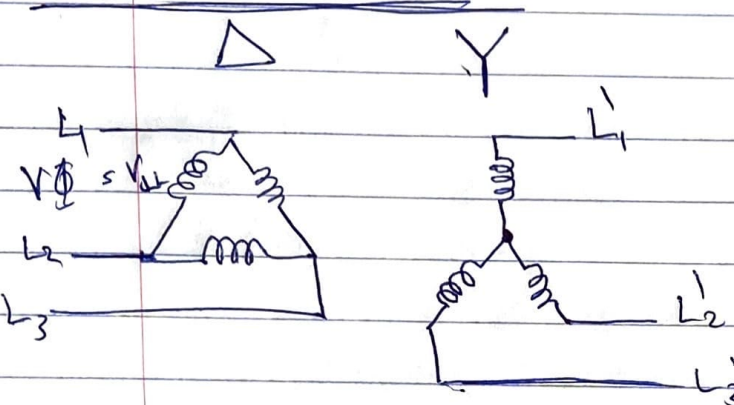
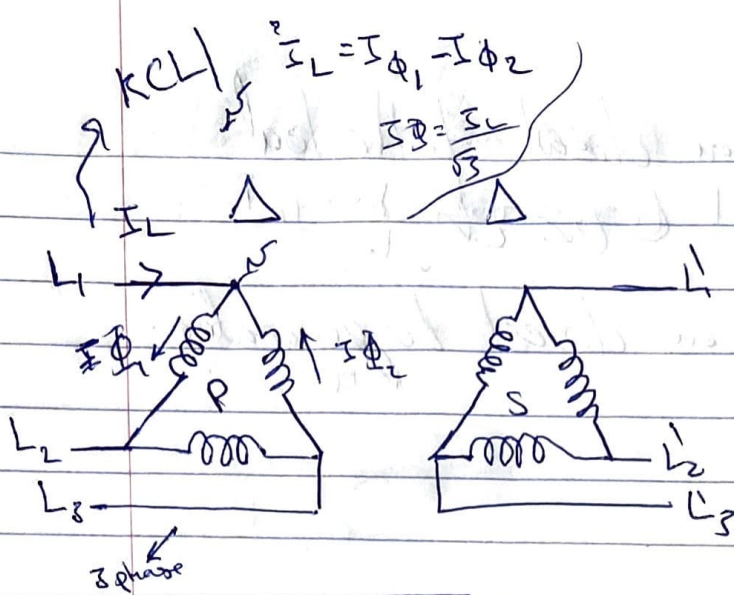
Core form $\rightarrow$ one phase



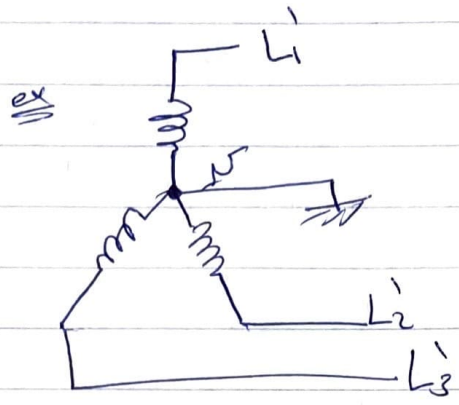
Three phase of core



shell form $\rightarrow$ 3 phase



* Y connection → when closest to the load
 * Δ connection when closest to generator.

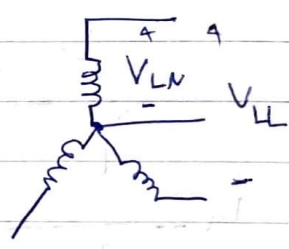


* Low voltage in Δ
 * High voltage in Y

* Bus bar made of steel ---
 ↳ rated power of transformer ← 6 cm radius

* Disk bables → not cylindrical

* V_{LN} (Voltage line to neutral)
 * V_{LL} → (Voltage line to line)



$$|V_{LL}| = \sqrt{3} V_{LN}$$

$$\Rightarrow V_{LL} > V_{LN}$$

$$P_{3\phi} = \sqrt{3} V_{LL} I_L \text{ PF}$$

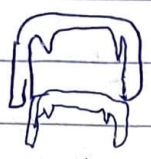
power for 3 phase

$$P_{3\phi} = 3 V_{LN} I_{\phi} \text{ PF}$$

$$P_{1\phi} = V I \text{ PF}$$

* Insulators / Pusher to
 صحن وفنجان مصنوع من الفايبر

High Voltage are big
 & small to low



جهاز التحويل الكهربائي
 الذي يرفع أو يخفض الجهد الكهربائي

* How to cold to reduce dissipation in the core

oil → fans → تبريد سطح القلب
 الفايبر
 fans → زيادة كمية تيار
 oil → top
 فيكون على سطح القلب فتزيد تيار درجة الحرارة وتزيد
 لا ينبغي

Losses
 • Eddy
 • Hysteresis
 core → at top (electromagnetic) flux

- loads —
- small
 - medium
 - large
 - comercial
 - residential

in Residential 2 — طاقتهم في البيوت

LN → 240

LL → 400

- Transformers Types

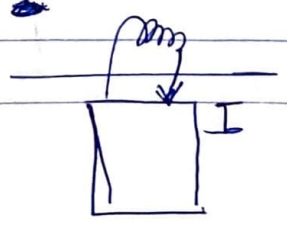
① Power → step up / step down

② Potential

→ أجهزة القياس
 لأنها تحتاج فولتية عالية

③ Current → (CT)

التيار العالي ليس فينا في كل meter



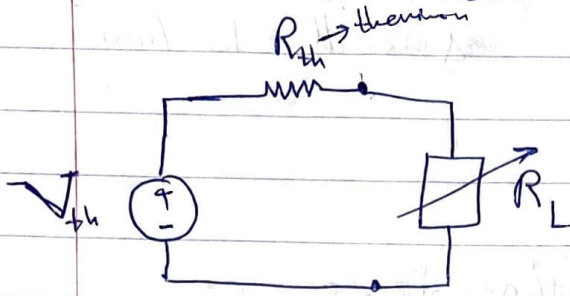
التيار في القلب

④ Isolation → no step up & no step down



⑤ Impedance matching

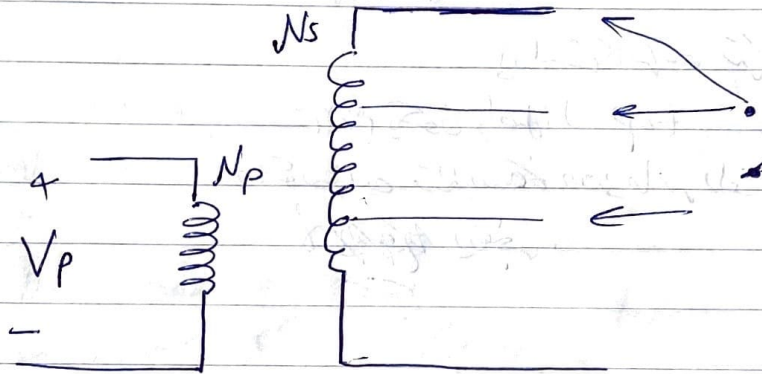
* Maximum Power Transfer



$$P_{LMax} = \frac{V_{th}^2}{4R_2}$$

as long as $R_L = R_{Th}$

Impedance
matching
transformer



So if we don't
want
to use
all turns

Why Shell is better

→ efficiency ↑ →
→ don't need air gap

sharp edges

reability →



distribution stream
في نقطة التوزيع

shell

لا حيز واحد كلهم
عزوا

generator في ال
والتوازي

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = a$$



* Ideal transformer $\rightarrow$ no losses

$$P_{in} = P_{out}$$

$$V_1 I_1 PF = V_2 I_2 PF$$

$$\text{also } Q_{in} = Q_{out}$$

$$PF = \cos(\theta_v - \theta_i)$$

phase shift between voltage & current

$$\frac{I_1}{I_2} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{1}{a}$$

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{1}{a}$$

* Types of power

P real power --- (W)

Q reactive power $\rightarrow Q = VI \sin(\theta_v - \theta_i)$ --- VAR

S complex power $\rightarrow S = P + jQ$ (VA)

$$S = \sqrt{P^2 + Q^2} \angle \tan^{-1}\left(\frac{Q}{P}\right)$$

$$= |S| \angle \theta$$

$$P_{app} = V_{rms} I_{rms} \text{ --- VA}$$

signal voltage



* transformer doesn't change angle

$$P_{in} = P_{out}$$

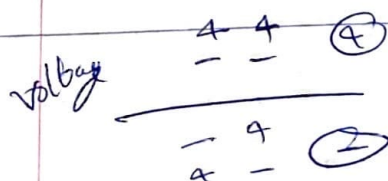
$$\cos(\theta_v - \theta_i) = \cos$$

(How to check? take signal & compare it with output)

but in 3 phase $\rightarrow$ θ changes

* Dot Convention (2 forms are for voltage polarity & one for current)

dot convention



$$\frac{V_1}{N_1} = \frac{V_2}{N_2}$$



current dot
إذا كان دخول ال
coil
current

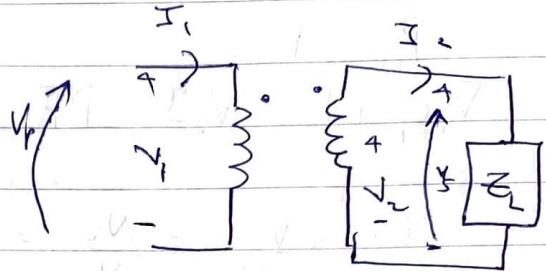
* Impedance reflection (from Thevenin equivalent circuit)

Impedance $\vec{Z} = \frac{\vec{V}}{\vec{I}}$ phasor voltage
phasor current

$$Z = X + jy$$

$$Z = |Z| \angle \theta$$

load $\vec{Z}_L = \frac{\vec{V}_2}{\vec{I}_2}$



$\vec{Z}'_L = \frac{\vec{V}_1}{\vec{I}_1}$ using dot convention
 $\vec{Z}'_L = \frac{\vec{V}_2 a}{\vec{I}_1} = \frac{\vec{V}_2 a}{\vec{I}_2 / a}$ $V_1 = V_2 a$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = a$$

~~$\vec{Z}'_L = \frac{\vec{V}_2}{\vec{I}_2} a$~~ $\vec{Z}'_L = \frac{\vec{V}_2}{\vec{I}_2} a^2$ (a²)

$$\boxed{\vec{Z}'_L = \vec{Z}_L a^2}$$

transformer from secondary side to primary side

* if from Primary to secondary

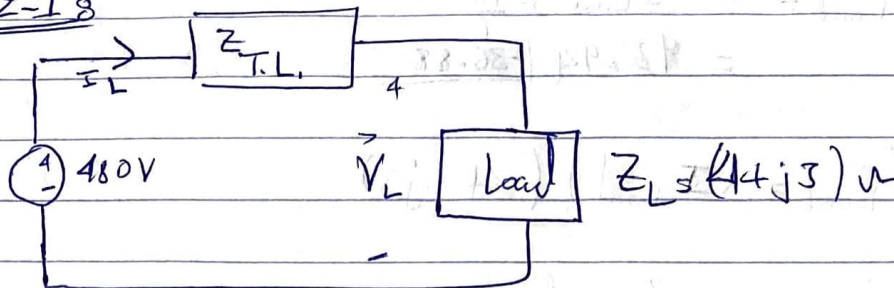
~~divide by a²~~ → divide by $\frac{1}{a^2}$

* $V(t) = 5 \cos(\omega t + \phi)$

$$\vec{V} = 5 \angle 0$$

* why we put a sign on the phasor?

Ex 2-18



① $V_L = ?$ $P_{losses} = ?$ → easiest reference to take

$$\begin{aligned} \angle I_L &= \frac{\vec{V}_{Generator}}{Z_{total}} = \frac{480 \angle 0^\circ}{(0.18 + j0.24) + (4 + j3)} \\ &= 90.8 \angle -87.8^\circ \end{aligned}$$

$$\vec{V}_{Load} = \vec{I}_L (Z_L) = 454 \angle -0.9^\circ \text{ volt}$$

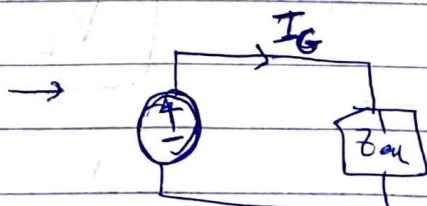
$$\begin{aligned} P_{losses} &= I^2 R \quad \text{→ real part in transmission line} \\ \text{T.L.} &= (90.8)^2 (0.18) \\ &= 1484 \text{ watt} \end{aligned}$$

②

$$\begin{aligned} Z_{load} &= a^2 Z_{load} \\ &= \left(\frac{N_1}{N_2}\right)^2 (4 + j3) = (100)(4 + j3) \Omega \end{aligned}$$

$$Z_{eq} = Z_{T.L.} + Z_{load} = 400.18 + j300.24 \Omega$$

$$\begin{aligned} Z_{eq} &= a^2 Z_{eq} \\ &= \left(\frac{N_1}{N_2}\right)^2 Z_{eq} = 5.003 \angle 36.88^\circ \Omega \end{aligned}$$



$$\Rightarrow \text{find } I_G = \frac{480 \angle 0^\circ}{5.003 \angle 36.88^\circ} = 95.94 \angle -36.88^\circ$$

$\angle I_{Line} = ?$

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} \Rightarrow \frac{I_G}{I_{Line}} = \frac{10}{1}$$

$$I_{Line} = \frac{I_G}{10} = 9.594 \angle -36.88^\circ \text{ A}$$

$$I_{Load} = I_{Line} \times 10$$

$$= 95.94 \text{ A} \quad \underline{36.88}$$

$$V_{Load} = (I_{Load}) (4 + j3)$$

$$P_{Losses} = I_{Line}^2 R$$

$$= (95.94)^2 (0.18)$$

$$= 16.7 \text{ Watts}$$

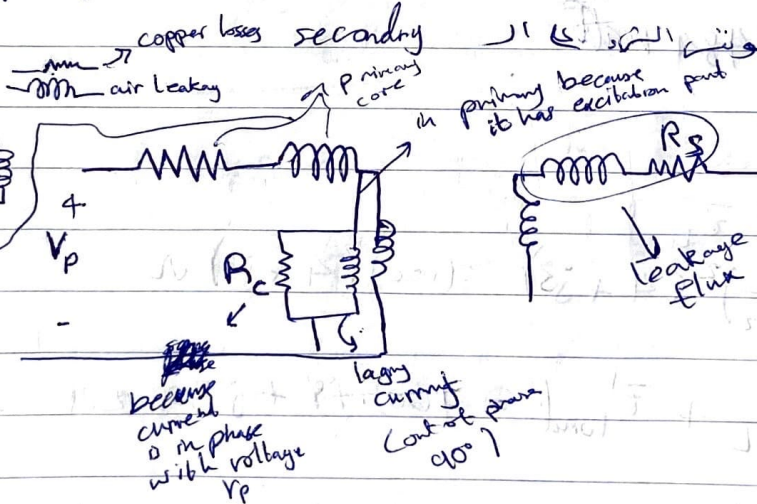
Transformer losses 16.7 W
 1500% in

all above were ideal transformer

in real life we need real/practical transformer

(Copper losses)

primary losses secondary losses conductor losses



eddy current & hysteresis losses

$$f = \frac{d\phi}{dt}$$

$$\phi = N_p i_p$$

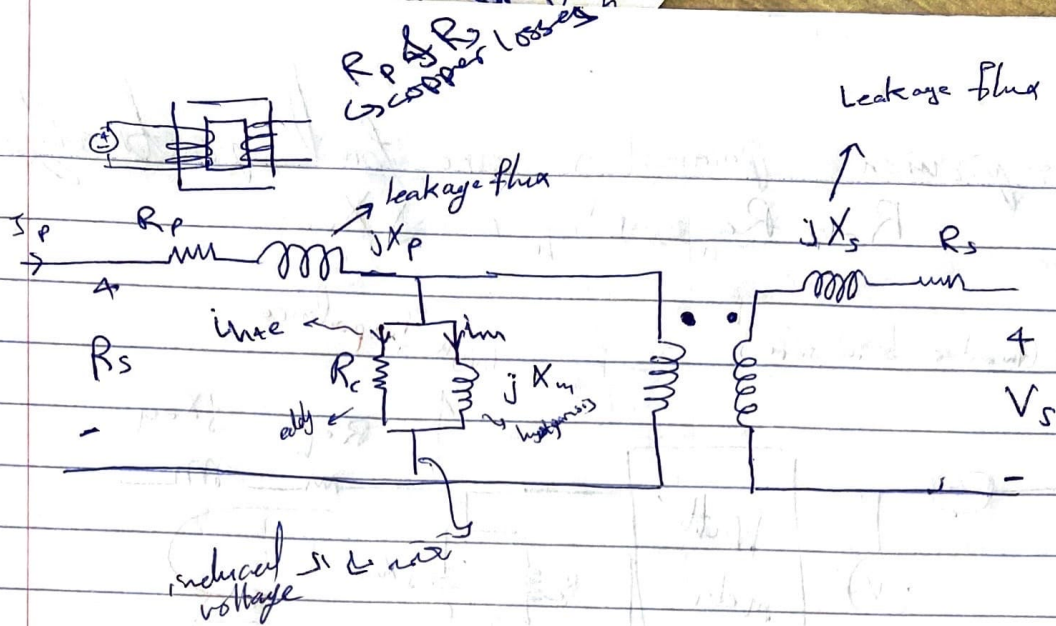
$$V_L = L \frac{di}{dt}$$

$$e_p = N_p \frac{d\phi}{dt}$$

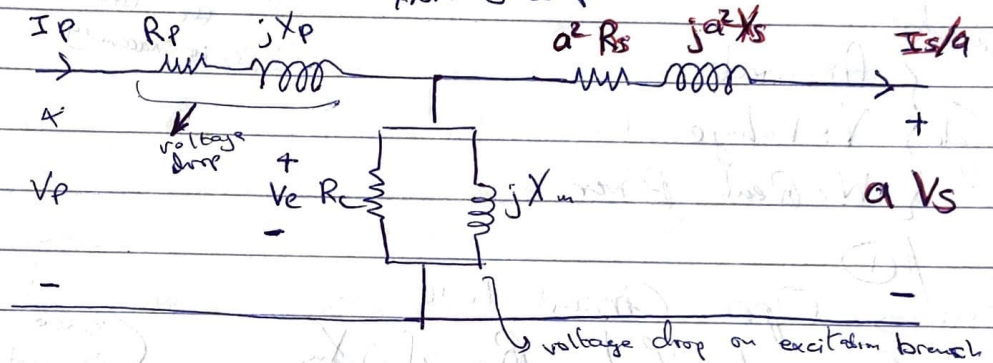
$$= N_p \frac{d(N_p i_p)}{dt}$$

$$= N_p^2 \frac{di}{dt}$$

$$V_L = L \frac{di(t)}{dt}$$

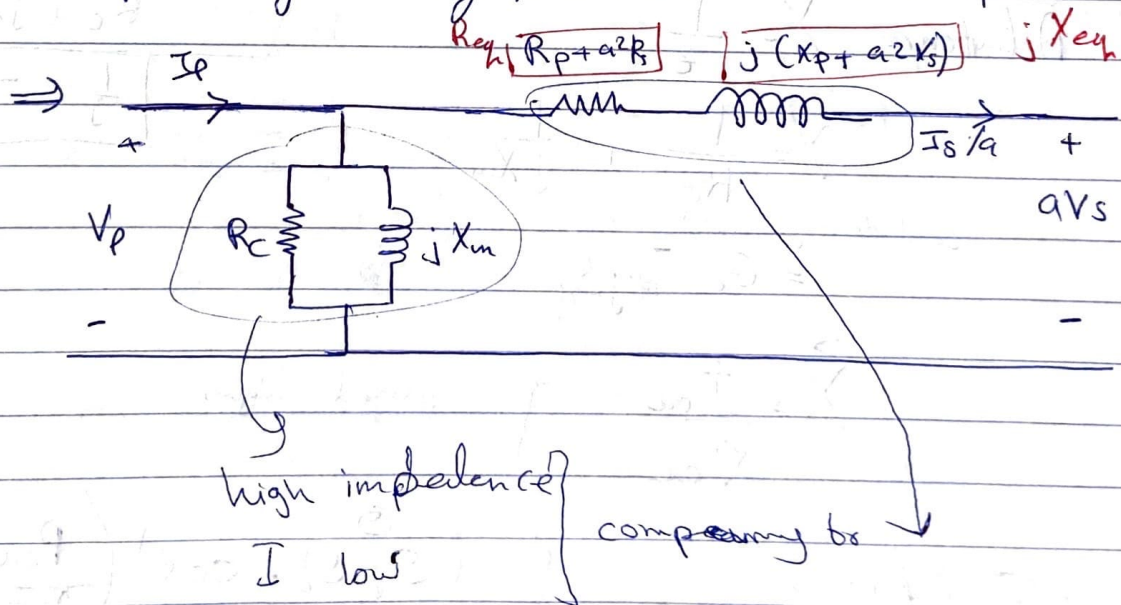


→ we need to do reflection to simplify the circuit -
from S to P



& also do reflection from P to S

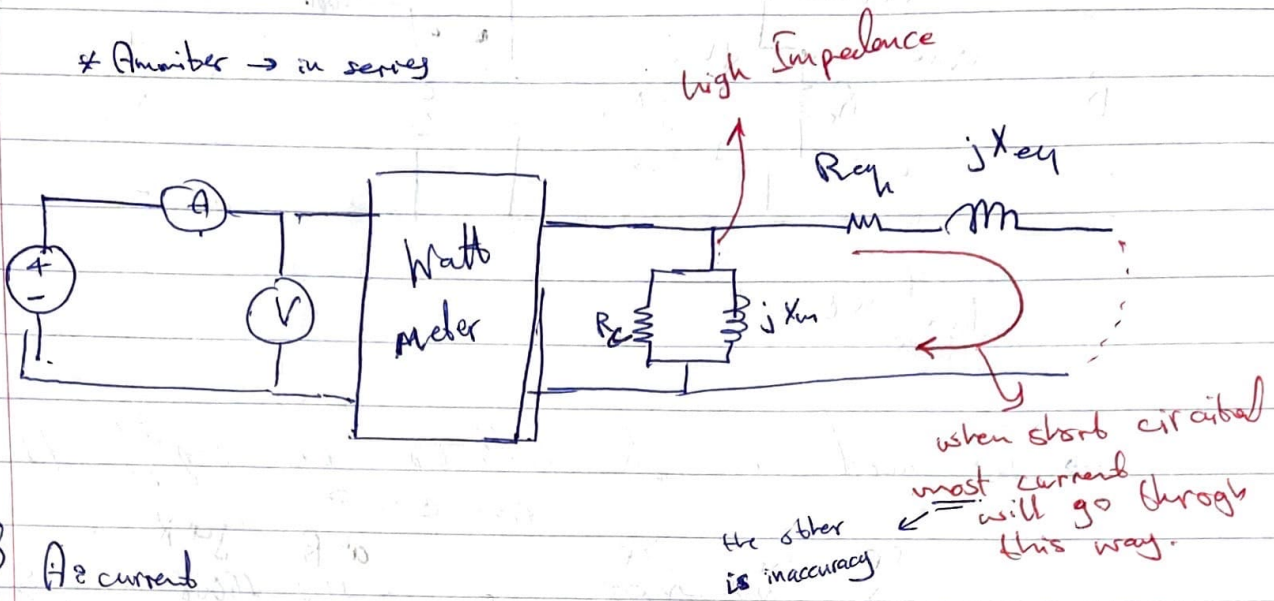
experimentally, they found that $V_c \approx V_p$



so some would remove
the excitation part

* previous parameters are found practically
 $R_c, R_{eq}, jX_{eq}, jX_m$

* Ammeter $\rightarrow$ in series



Numerical Values
 no angle
 I : current
 V : Voltage
 W : Real Power

Method ① Open Circuit test
 $\rightarrow$ use to find R_c & jX_m

(since the excitation part is not an open loop as the other when I_p arrives to ~~the~~ distribute)

impedance

$V_{o.c}, I_{o.c}, P_{o.c}$

Admittance $Y = \frac{1}{Z}$

$$Y = \frac{1}{R_c} + \frac{1}{jX_m}$$

conductance $\leftarrow$
 $= G_c - jB_m$

$$\vec{Y} \approx \frac{\vec{I}_{o.c}}{\vec{V}_{o.c}} \quad \left. \vphantom{\vec{Y}} \right\} \text{ without angles}$$

* To find Angles

$$P = VI \text{ PF}$$

$$PF = \cos(\theta_v - \theta_i)$$

$$PF = \frac{P}{VI}$$

$$(\theta_v - \theta_i) = \cos^{-1} \left(\frac{P_{o.c}}{V_{o.c} I_{o.c}} \right)$$

now

$$\vec{Y} = \frac{\vec{I}_{o.c}}{\vec{V}_{o.c}} = \frac{\vec{I}_{o.c}}{\vec{V}_{o.c}} \angle \theta_i$$

$$= \frac{\vec{I}_{o.c}}{\vec{V}_{o.c}} \angle (\theta_i - \theta_v)$$

the found ~~before~~ is $\theta_v - \theta_i$

$$\vec{Y} = \frac{I_{o.c}}{V_{o.c}} \angle -\cos^{-1} \frac{P_{o.c}}{V_{o.c} \cdot I_{o.c}}$$

$$\vec{Y} = X \angle \theta$$

$$= X \cos \theta + j X \sin \theta$$

$$\Rightarrow R_c = \frac{1}{X \cos \theta} \quad , \quad X_m = \frac{1}{X \sin \theta}$$

Method ②: Short circuit the secondary

V_{sc}, I_{sc}, P_{sc} (from measurement devices)

$$\vec{Z} = \frac{\vec{V}}{\vec{I}}$$

$$= \frac{V_{sc} \angle \theta_v}{I_{sc} \angle \theta_i}$$

$$P_{sc} = V_{sc} I_{sc} \cos \theta$$

$$(\theta_v - \theta_i) = \cos^{-1} \left(\frac{P_{sc}}{V_{sc} I_{sc}} \right)$$

$$\Rightarrow \vec{Z} = \frac{V_{sc}}{I_{sc}} \angle \cos^{-1} \left(\frac{P_{sc}}{V_{sc} I_{sc}} \right)$$

$$= X + jY$$

$$R_{eq} = X \quad , \quad X_{eq} = Y$$

Example 2-2

apparent power = 20 kVA

8000/240

$f = 60 \text{ Hz}$

turns ratio $\frac{P}{S} = \frac{8000}{240}$

↓

$R_c \text{ \& } jX_m$

← open circuit →

low

voltage side →

on secondary

we use the minimum voltage to be short circuited due to measurement performance

$R_{eq} \text{ \& } jX_{eq}$

← short circuit →

high

voltage side →

on primary

* $R_c \text{ \& } jX_m$

$$Y = \frac{I_{oc}}{V_{oc}} \left| -\cos^{-1} \left(\frac{P_{oc}}{V_{oc} I_{oc}} \right) \right.$$

phasor

↓ to

rectangular

$$= G_c - jB_m$$

$$R_c = \frac{1}{0.00693} = 1441 \Omega$$

$$X_m = \frac{1}{0.02888} = 34.63 \Omega$$

* $R_{eq} \text{ \& } jX_{eq}$

$$Z = R_{eq} + jX_{eq}$$

$$= \frac{V_{sc}}{I_{sc}} \left| \cos^{-1} \left(\frac{P_{sc}}{V_{sc} I_{sc}} \right) \right.$$

$$= (38.4 + j192) \Omega$$

Q is to primary side

→ short circuit

open circuit → needs to be moved to primary from secondary

$$\Rightarrow a = \frac{8000}{240}$$

$R_c \text{ \& } jX_m$

must be multiplied by a^2

Per Unit Value
 deleted by per unit value $\leftarrow$ utility gives a $\parallel$, transformer more simplification
 voltage needed $\leftarrow$ max power generator give $\leftarrow$ voltage current power impedance
 used in per value $\leftarrow$

Quantity per unit = $\frac{\text{actual value}}{\text{base value of quantity}}$

$1\phi \rightarrow V_{LN}$

$3\phi \rightarrow V_{LN}$
 $\quad \quad \quad \rightarrow V_{LL}$

1ϕ $\rightarrow$ apparent power
 $I_{base} = \frac{S_{base} 1\phi}{V_{base LN}}$

$Z_{base} = R_{base} = X_{base} = \frac{V_{base LN}}{I_{base}}$

$3\phi \rightarrow$ either we calculate for 1ϕ & multi. by 3
 or depend on 3ϕ eqs.

Example 2-38

Per Unit = $\frac{\text{Actual Value}}{\text{Base Value}}$

* base voltage = 480 voltage

* base power = 10 kVA

5 zones $\rightarrow$ for each find base voltage & base power

① * for zone 1:

$$V_{\text{base},1} = 480 \text{ V}$$

$$S_{\text{base},1} = 10 \text{ kVA}$$

$$I_{\text{base},1} = \frac{S_{\text{base},1}}{V_{\text{base},1}} = \frac{10 \text{ k}}{480} = 20.83 \text{ A}$$

$$Z_{\text{base},1} = \frac{V_{\text{base},1}}{I_{\text{base},1}} = \frac{480}{20.83} = 23.04 \Omega$$

* for zone 2:

$$V_{\text{base},2} = 10 \times 480 = 4800 \text{ volt} \quad \left(\text{using } \frac{V_1}{V_2} = \frac{N_1}{N_2} \right)$$

$$S_{\text{base},2} = 10 \text{ kVA} \quad (\text{power doesn't change, ideal transformer})$$

$$I_{\text{base},2} = \frac{10 \text{ k}}{480} = 2.083 \text{ A}$$

$$Z_{\text{base},2} = \frac{4800}{2.083} = 2304 \Omega$$

* for zone 3:

$$V_{\text{base},3} = \frac{4800}{20} = 240 \text{ volt}$$

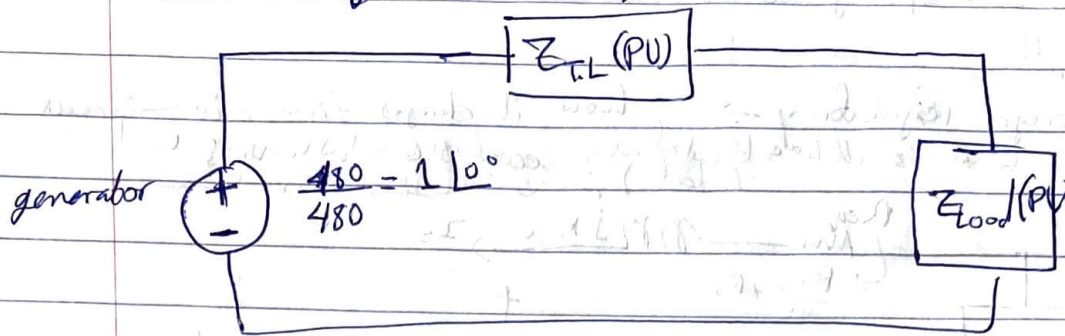
$$S_{\text{base},3} = 10 \text{ kVA}$$

$$I_{\text{base},3} = \frac{10 \text{ k}}{240} = 41.67 \text{ A}$$

$$Z_{\text{base},3} = \frac{240}{41.67} = 5.76 \Omega$$

⑥

transformer Z_L
impedance in zone 2



$$Z_{T.L.} (PU) = \frac{20 + j60}{2304} = (0.0087 + j0.026) \text{ per unit}$$

$$Z_{Load} (PU) = \frac{10 \angle 30^\circ}{5.76} = 1.736 \angle 30^\circ$$

$$R_{Load} + jX_{Load}$$

$\downarrow$ $\downarrow$

$1.736 \cos 30^\circ$ $1.736 \sin 30^\circ$

⑦ $I_{PU} = \frac{1 \angle 0^\circ}{Z_{T.L.} (PU) + Z_{Load} (PU)}$

$$= 0.569 \angle -50.6^\circ \text{ PU}$$

⑧ $P_{Load} (W) = I^2 R \rightarrow \text{per watt}$

$$= (0.569)^2 (1.736 \cos 30^\circ)$$

$$= 0.487 \text{ watt}$$

⑨ $P_{actual} = PU \times \text{base val}$

$$= 0.487 \times 10 \text{ KVA}$$

$$= 4870 \text{ watt}$$

losses supplied to the load

⑩ calculate actual I_{Load}

$$I_{Load \text{ actual}} = 0.569 \angle -50.6^\circ \times 41.67$$

⑪ $P_{losses} = I^2 R$

$$(PU) = (0.569)^2 (0.0087)$$

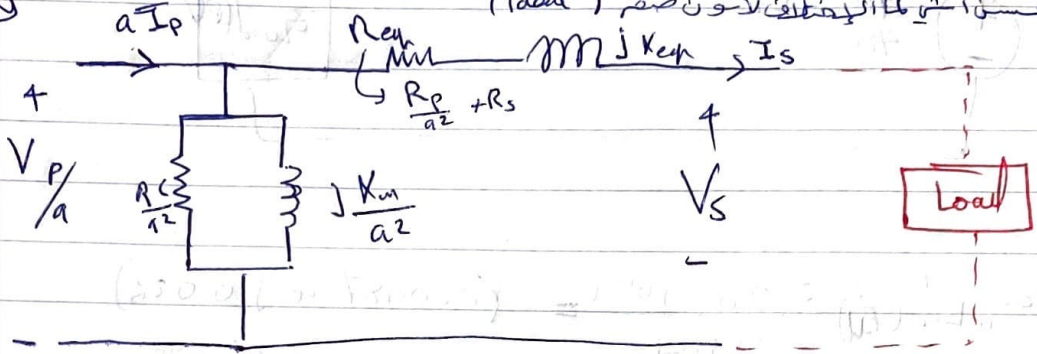
$$= 0.00282$$

$$0.00282 \times 10 \text{ K} = 28.2 \text{ Watt}$$

on same rated value
 * When comparing two transformers
 weight,

refer to secondary

Voltage regulation → how it changes from min → max
 transformer's full load at B rated at secondary (initial) (ideal) is 0.5% (initial) (ideal) is 0.5%

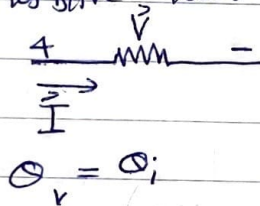


$$\text{Voltage Regulation} = \frac{V_{nl} - V_{fl}}{V_{fl}} \times 100\%$$

no load full load

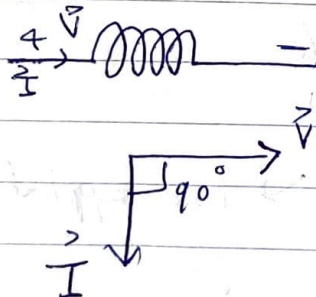
* Loads types:

1) Resistive load



if phase voltage in this direction → $\vec{V}$
 phase current is also → $\vec{I}$

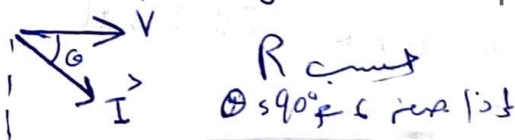
2) Pure Inductive



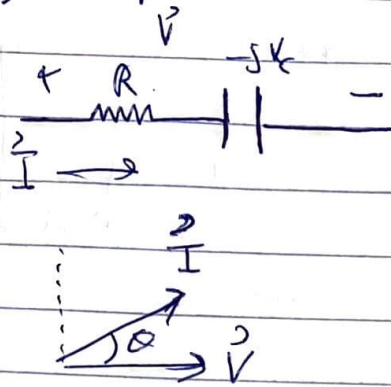
3) Pure capacitive → current is leading by 90°

90°

4) Inductive load $R + jX_L$



5) Capacitive load

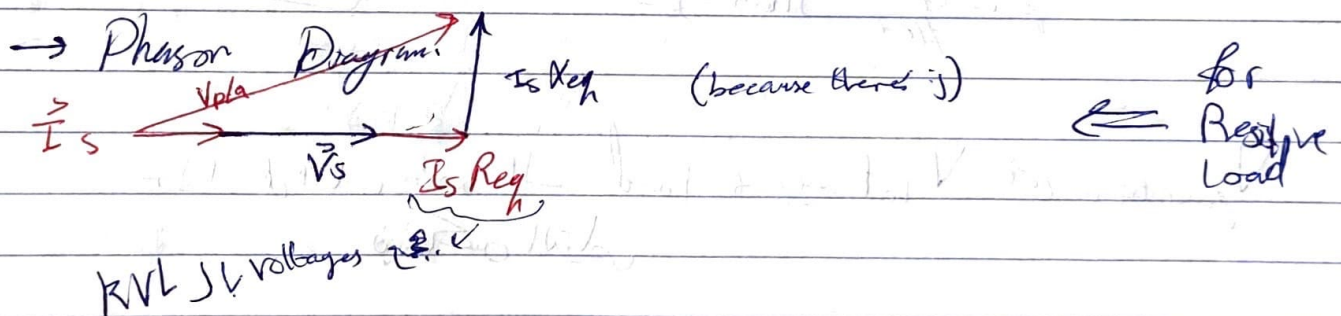


① & ④ & ⑤ → will be used to compare two transformers
 connect on load & see difference
 in previous circuit

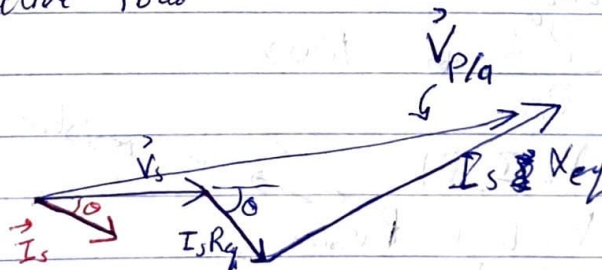
⇒ Do KVL

$$-V_{p/a} + I_s (R_{eq} + jX_{eq}) + V_s = 0$$

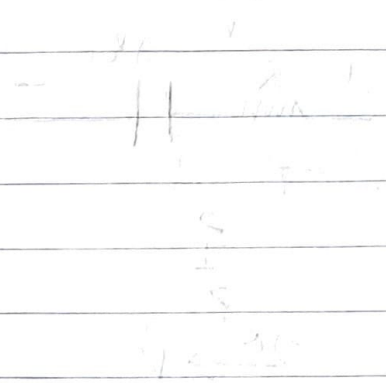
$$V_{p/a} = V_s + I_s (R_{eq} + jX_{eq})$$



* for inductive load



back mapping (f)



1/2

in resistive

الضلع من الكبريت وتو

IVA

more possible blank

indone

in capacitive

in cap

۱۰۰٪ کمال انسانیت

efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

100% in resistive paths (as calculating real power)

$R_{C_{at}}$ & R_{eq}

1

→ P_{core} (eddy & hysteresis)

→ P_{cu} (copper)

$$\Rightarrow \eta = \frac{V_s I_s \cos \phi}{P_{cu} + P_{core} + V_s I_s \cos \phi} \times 100\%$$

* $\rightarrow$ shell
 * $\rightarrow$ core

Reliability
 in shell if its broken
 in core if its broken

Example 2-58

$$S = 15 \text{ kVA}, \quad \frac{2300}{230} \text{ volt}$$

open circuit on low voltage because $V \uparrow$

$$Y = \frac{I_{sc}}{V_{oc}} \left[-\cos^{-1} \left(\frac{P_{oc}}{V_{oc} I_{sc}} \right) \right] = 0.000934 - j 0.00908 \text{ S}$$

$$R_c = \frac{1}{0.000934} = 1050 \Omega$$

$$X_m = \frac{1}{0.00908} = 110 \Omega$$

$$Z = \frac{V_{sc}}{I_{sc}} \left[1 + \cos^{-1} \left(\frac{P_{sc}}{V_{sc} I_{sc}} \right) \right]$$

$$R_{eq} = 4.45$$

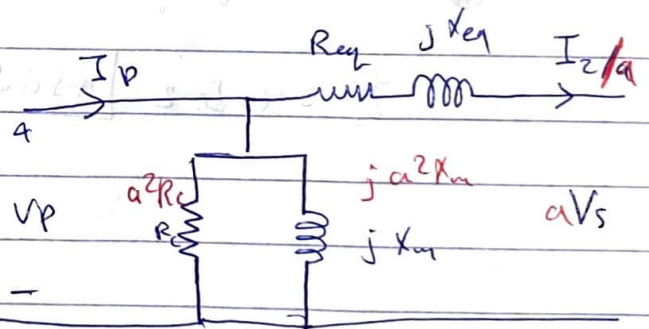
$$jX_{eq} = j 6.45$$

① referred for low voltage (primary side)

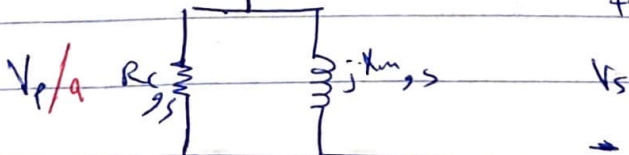
$$R_{eq} \neq \frac{R_c}{a^2}$$

$$X_{eq,lp} =$$

$$\frac{R_{eq}}{a^2} \quad \frac{jX_{eq}}{a^2}$$



②



$$\textcircled{3} \quad VR = \frac{V_{nl,s} - V_{fl,s}}{V_{fl,s}} \times 100\%$$

at open circuit secondary side

$$VR = \frac{V_{P/a, nl} - V_{s, fl}}{V_{s, fl}}$$

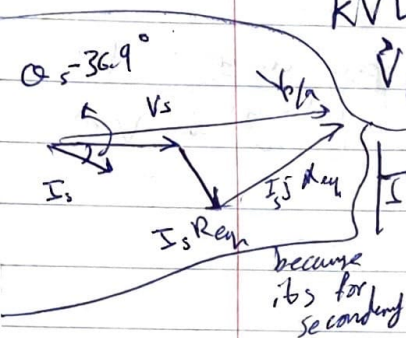
KVL defn,
 $V_{nl,s} = V_{p/s}$

at 0.8 lagging:

$$\text{KVL: } -\vec{V}_{P/a} + \vec{I}_s (R_{eq} + jX_{eq}) + V_s = 0$$

$$\vec{V}_{P/a} = \vec{V}_s + \vec{I}_s (R_{eq} + jX_{eq})$$

because I_s is lagging



$$I_s = \frac{15k}{230}$$

$$\Rightarrow \vec{I}_s = \frac{15k}{230} \angle -\cos^{-1} PF$$

$$= 65.2 \angle -36.9^\circ \text{ A}$$

refering
to secondary
side

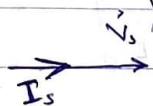
$$\vec{V}_{P/a} = 230 \angle 0^\circ + 65.2 \angle -36.9^\circ (0.04 + j0.0648)$$

$$= 234.85 \angle 0.4^\circ \text{ volt}$$

$$\Rightarrow VR = \frac{234.85 - 230}{230} \times 100\%$$

at unity $PF = 1$

$$\vec{I}_s = 65.2 \angle 0^\circ \text{ A}$$



at leading power factor

$$\vec{I}_s = 65.2 \angle +36.9^\circ$$

$P_{app} = 15 \text{ kVA}$

$P_{real} = 15k \times PF$

but $P = 8 \text{ W PF}$

$$\rightarrow I_s P_{PF}$$

$$= \frac{15kPF}{230 PF} \angle -\cos^{-1} PF$$

as magnitude

$$\textcircled{5} \quad \eta = \frac{P_{out}}{P_{in}} + 100\%$$

$$P_{out} = V_s I_s \text{ PF}$$

$$= (230)(65.2)(0.9) =$$

$$P_{in} = P_{out} + P_{losses}$$

Core losses

Copper losses

P real power absorption by $\underline{R}$

$$P_{core} = \frac{(V_p/4)^2}{R_c}$$

$$= \frac{(234.85)^2}{1050}$$

$$P_{cu} = I_s^2 R_{eq}$$

$$= (65.2)^2 (0.044)$$

Q reactive power on L & C

$-j\omega L$ $+j\omega C$

$\textcircled{6}$ Find η for reactive power

$$\eta = \frac{Q_{out}}{Q_{in}} + 100\%$$

$$= \frac{V_s I_s \sin(-36.9)}{V_s I_s \sin(-36.9)} + 100\%$$

* Three Phase Transformer

in Φ_1 , ratio $\frac{V_P}{V_S}$

in Φ_3 $\Delta \Delta$, $Y Y$ no change in ratio
 $\begin{matrix} \Delta & \Delta \\ \text{LL} & \text{LN} \end{matrix}$

but in ΔY , $Y \Delta$ $\rightarrow \sqrt{3}$ times
 $\begin{matrix} \Delta & Y \\ \text{LL} & \text{LN} \end{matrix}$

$$P_{\Phi} = \sqrt{3} V_L I_L \text{ PF}$$

$$P_{\Phi} = 3 V_{LN} I_{\Phi} \text{ PF}$$

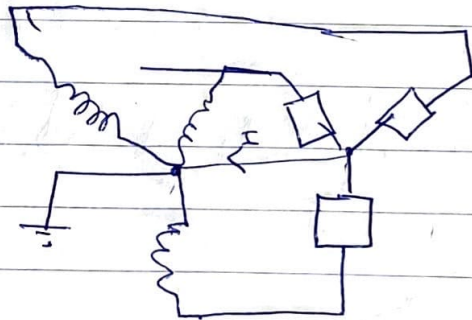
$\rightarrow$ for single

$$S_{\Phi} = \frac{S}{3}$$

* $Y Y \Rightarrow$ load $\rightarrow$ 1. Y عبور با یک بار load

Problems

مت-symmetrical جری في خط راجع $\leftarrow$ اگر به یک بار N $\rightarrow$ GND solidly grounded



② $\leftarrow$ 3rd harmonic $\leftarrow$ build up voltage $\leftarrow$ raised rate

$\leftarrow$ اگر به یک بار Δ به یک بار Y (load)
 (add new winding & auxiliary)

Assignment:

① What is the open-delta connection for transformer?
When do we use it?

→ gold connection

② What is the inrush current in transformer?

next Monday

22/12 Midterm

